OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

INAUGURAL LECTURE SERIES 287

URBANIZATION, FRESHWATER BIODIVERSITY CONSERVATION AND THE CRITICAL ROLE OF AQUATIC INSECTS

By

SYLVESTER SUNDAY OGBOGU, FESN

Professor of Zoology

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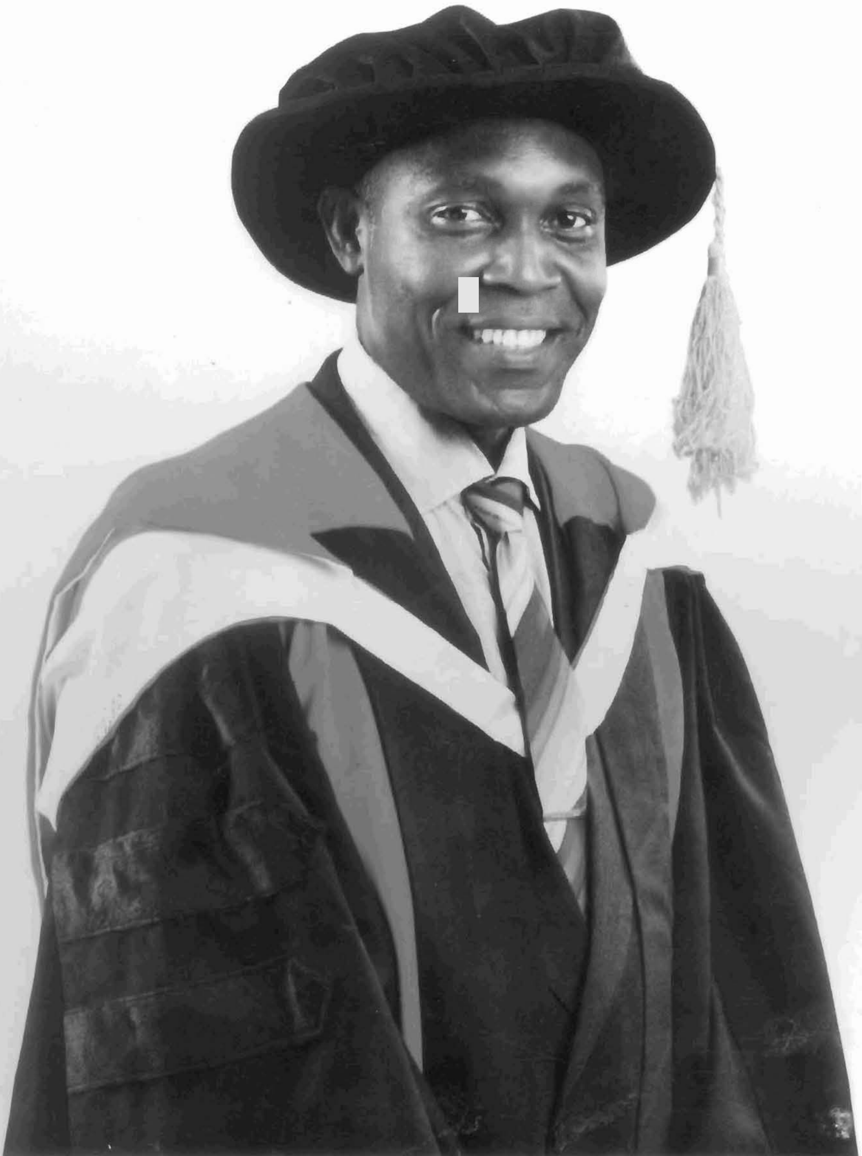

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An Inaugural Lecture Delivered at Oduduwa Hall,
Obafemi Awolowo University, Ile-Ife, Nigeria
On Tuesday, 24th May, 2016

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ISSN 0189-7848

Printed by
Obafemi Awolowo University Press Limited,
Ile-Ife, Nigeria.

1. PREAMBLE

The Vice Chancellor Sir, Principal Officers of the University, Members of the University Council, Provosts, Deans, Directors, colleagues, students, distinguished ladies and gentlemen, It is with deep sense of humility and gratitude to God that I stand before you today to deliver the 287th Inaugural Lecture of Obafemi Awolowo University, Ile-Ife and the 11th from the Department of Zoology.

Permit me to give a concise account of what led to my decision to study Zoology in the University of Ibadan and the choice of the Aquatic or Freshwater Entomology as a sub-discipline in Zoology. As a young boy in the primary school, I was curious about the diversity of organisms and spent most of my time chasing, collecting and playing with grasshoppers, birds and other animals, which was thought then as serendipity to my age mates. This enthusiasm for the study of life fuelled my determination to study all kinds of animals during my tertiary education. It was my dream to work on animals, although the societal influence of aspiring to be a medical doctor was also a desire.

When I was admitted into the University of Ibadan to read Zoology, it was clear to me that the divine hand of God was at work in my choice of career as an academic, because majority of my lecturers encouraged me to proceed for postgraduate studies.

On returning to the University of Ibadan for my postgraduate studies, I had no problems in the choice of a sub-discipline. I recollect with nostalgia that when late Professor Samuel Afolabi Toye addressed my M.Sc. Entomology class, on the need for someone to embark on the study of insect diversity in aquatic ecosystems as a postgraduate research project, I had no hesitation in signifying my interest. Professor A. Titi Hassan was on hand as the most qualified to supervise my M.Sc dissertation, having worked extensively on the ecology of dragonflies. Professor Hassan willingly accepted me and gave me a research topic on the feeding mechanisms and habits in a species of dragonfly. My

M.Sc. dissertation exposed me to many phenomena in aquatic ecosystems and elicited enormous curiosity in me.

On completion of the M.Sc. programme in 1987, I did not hesitate to continue, having qualified to embark on a doctoral degree programme. My research foray observed and determined the factors that influenced the diversity and abundance of Mayflies (Ephemeroptera) in tropical man-made reservoirs. Since then, I have approached all my research work with a primary goal – to find out what is there in any aquatic ecosystem and how it survives. In this inaugural lecture, titled "Urbanization, Freshwater Conservation and the Critical Role of Aquatic Insects", I shall discuss the negative impact of urbanization on the integrity of freshwater ecosystems. Using my knowledge of aquatic insect diversity and community structure in the ecosystems, I shall proffer measures aimed at mitigating the impact.

2. INTRODUCTION

2.1 Urbanization

The rate at which the world is undergoing urban growth is quite alarming. More than half of the world's population is resident in towns and cities. It has been predicted that by year 2030, this number will further increase given the current global problem of migrations across cities, countries and continents. The attendant rapid urbanization brings huge socioeconomic and environmental transformations especially in Africa and Asia. Although urbanization is expected to bring in a new era of well-being, efficient and sustainable resource utilization and economic growth, it often ushers in social divide, with high level of poverty in the lives of a sizeable proportion of populations in slums and informal settlements coexisting with wealthy communities.

The effects of urbanization are not limited to its direct impact on the lives of people. It also affects organisms and other living systems in the environment. One common effect is the impoverishment of freshwater (reservoir, stream and river) biota as a result of generated waste dumping and inflow of run-off from watersheds into the aquatic ecosystems in urban areas (Fig. 1). The impairment, popularly termed "urban stream syndrome" (Booth *et al.* 2016) is evidenced by degraded physico-chemical conditions, alteration of community structure, reduction in diversity and/or outright extermination of aquatic insects and other plant and animal communities in the ecosystems.

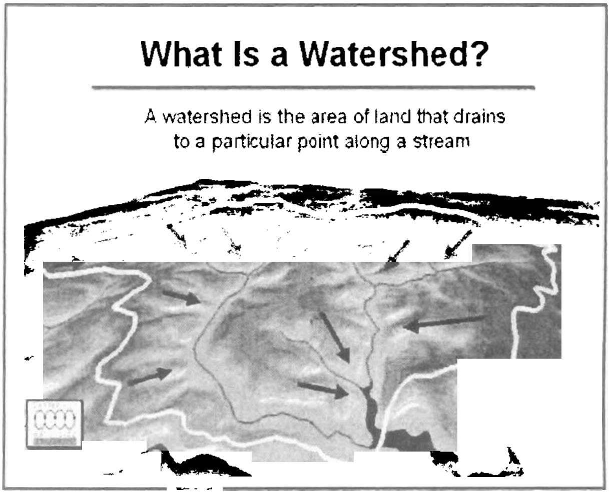


Figure1. An illustration of a watershed (springfieldohio.gov)

2.2 Freshwater Biodiversity Conservation

Conservation is the sustainable use of resources which integrates protection with exploitation. Bearing in mind that preservation is a subset of conservation, meaning to keep something without altering or changing it, freshwater conservation can therefore be explained as all management practices that are directed at maintaining the biological integrity (good health) of freshwater ecosystems. It seeks to protect, preserve and restore the health and biological integrity of freshwater ecosystems and its biodiversity, including the diversity of species. This may involve practices that ensure that renewable resources in them are not over-utilized. Freshwater conservation also involves monitoring and shaping the use of watersheds which freshwater ecosystems drain. By so doing, impairment is prevented, reduced and controlled.

To articulate freshwater conservation strategies, the International Union of the Conservation for Nature and Natural Resources (IUCN) in 1995 provided the framework (Article 13.1 of the International Covenant on Environment and Development) for the preservation of the health of natural ecosystems. The article states that "parties shall pursue sustainable development policies aimed at the eradication of poverty, the general improvement of economic, social and cultural conditions, the conservation of biological diversity, and maintenance of essential ecological processes and life-support systems". It charged stakeholders in affected systems to take appropriate measures to conserve and where necessary and possible, restore natural systems which support life on Earth in all its diversity, including biological diversity, and to maintain and restore the ecological functions of these systems as an essential basis for sustainable development, including inter alia,

(a) Forests as climate regulators and as natural means to control erosion and floods;
(b) Freshwater wetlands and floodplains as recharge areas for ground waters, floodwater and buffers, filters and oxidizing areas for contaminants.

To give attention to the recommendation 'b' above, freshwater Biologists in general and Aquatic Entomologists in particular have been interested in the nature of aquatic insect and other macroinvertebrate communities in both impacted and non-impacted freshwater ecosystems (Clements 1994, Sykora *et al.*, 1997, Meyer 1997, Maret *et al.*, 2003, Kreutzweiser 2008, Somers *et al.*, 2013, Vander Laan, *et al.*, 2003 and Arce *et al.*, 2014). They have also provided information aimed at designing freshwater conservation strategies using the knowledge gained from aquatic insect ecology (e.g. Saunders *et al.*, 2002, Strayer, 2006 and Suski and Cook 2007).

2.3 Aquatic Insects

Many members of the arthropod group of animals (invertebrate animals with jointed appendages) including insects, live in all kinds of water bodies. These insects (aquatic insects) are known to spend their entire lives or at least water-borne at some point in their life cycles in water bodies. One of the most amazing characteristics of aquatic insects is the diversity of habitats in which they can be found. There is no aquatic habitat that is too small, too large, too cold, too hot, too muddy, with oxygen too low, with currents too fast, or even with too much pollution for some kind of aquatic insects to live there. The only exception is perhaps the marine environments (oceans and bays). However, a few of them live on coral reefs, in tidal pools of marine environments, and in estuaries, where there is a mixture of fresh inland water and salty ocean water.

Many aquatic insects are often not seen unless one curiously explores water bodies. Popular among aquatic insects are the mosquitoes which are considered harmful because they are vectors of pathogens that infect man and his animals. A lot more are quite useful in a way. They include the mayflies (Order: Ephemeroptera), dragonflies and damselflies (Odonata), stoneflies (Plecoptera) true bugs (Hemiptera), fishflies, dobsonflies and alderflies (Megaloptera), caddisflies (Trichoptera), aquatic Caterpillars (Lepidoptera), water beetles (Coleoptera), and true flies (Diptera) (Figs 2).

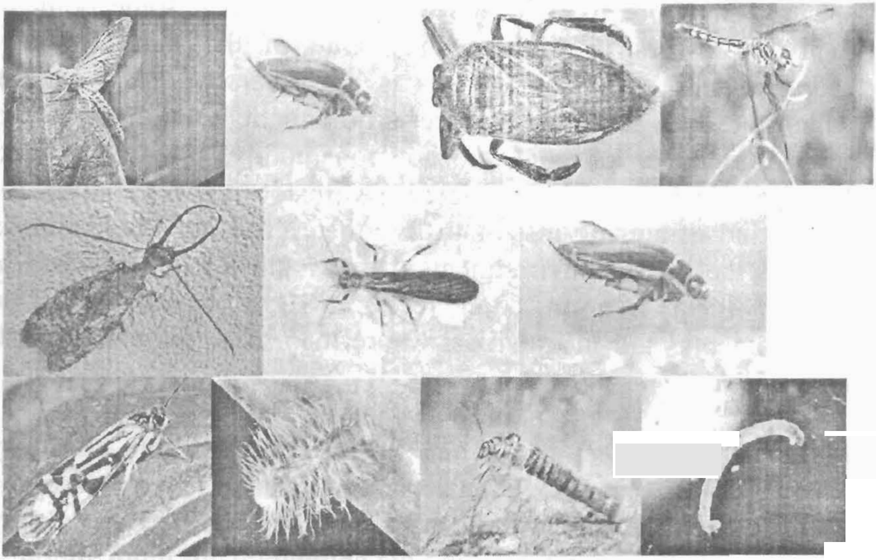
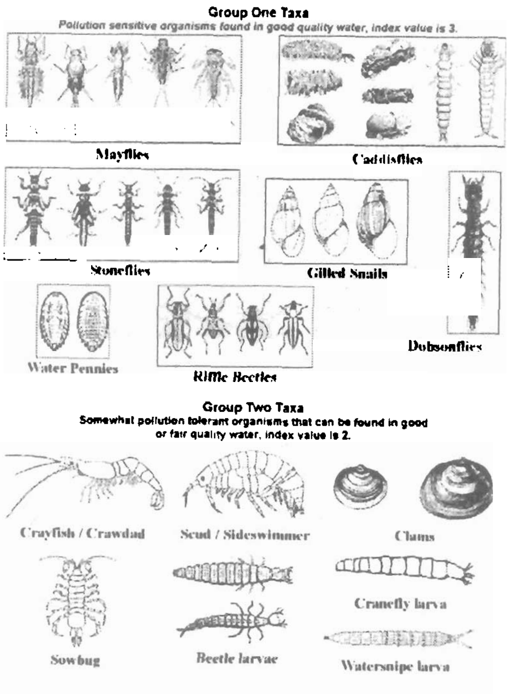


Figure 2. An array of aquatic insects.

2.4 Aquatic insects and water quality assessments

Enormous information exists in literature on studies which show that aquatic invertebrates (insects in particular) serve as indicators of water quality. The interest in aquatic insects stems from the fact that they are affected by physico-chemical and biological conditions of water bodies. The juvenile stages can not escape pollution, hence they show the effects of short- and long-term pollution events and the aggregate impacts. In addition to being a critical part of aquatic food web, many species are intolerant to pollution and accentuate habitat loss not captured by traditional water quality assessments. Aquatic insects are easy to sample and identify. Apart from direct use of water samples to determine the concentration of various metals, dissolved oxygen, organic matter and hydrogen ion, biologists are able to assist the water chemists by using aquatic insects as indicators of water quality. Because some aquatic insects are more sensitive to pollution than others, it is easy to hypothesize a pollution event if a water body is inhabited by insects that are pollution-tolerant and devoid of pollution-sensitive ones (Fig. 3). This is the principle behind biological water quality assessments. They tell us clearly if water bodies are impaired (or sick) due to pollution or habitat loss.



Figures 3. Pollution sensitive and tolerant macroinvertebrates.

Aquatic insects also provide some freshwater ecosystem services. Through their functional feeding attributes (Fig. 4), they play important roles in energy flow and nutrient dynamics in the aquatic food web. They are involved in a number of important ecosystem processes including leaf-litter breakdown especially in urban watersheds.

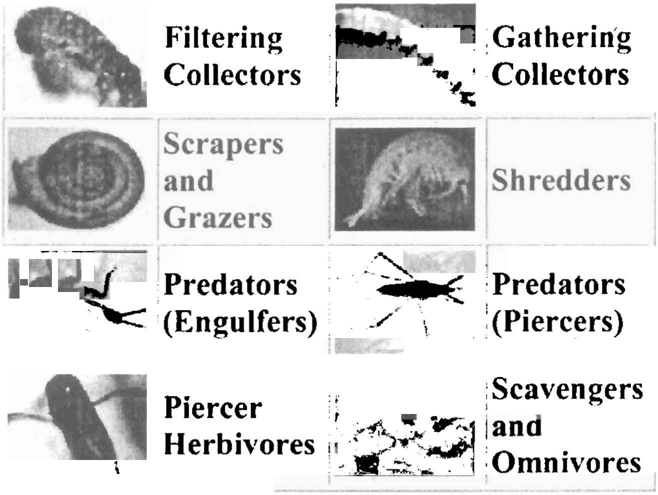


Figure 4. **Functional feeding groups in aquatic macroinvertebrates.**

For example the shredders, gathering and filtering collectors are key players in generating fine particulate organic matter (FPOM) from coarse particulate organic matter (CPOM) and dissolved organic matter (DOM), particularly through their waste products. FPOM is an important high quality food material for other invertebrates and microbes because it is higher in nutrient content than the conditioned leaves (Fig. 5). Therefore, for a conservation biologist who is interested in freshwater ecosystems, the knowledge of composition and distribution, adaptations, niches, food habits, food webs and life cycles of aquatic insects, as well as water quality of water bodies is imperative.

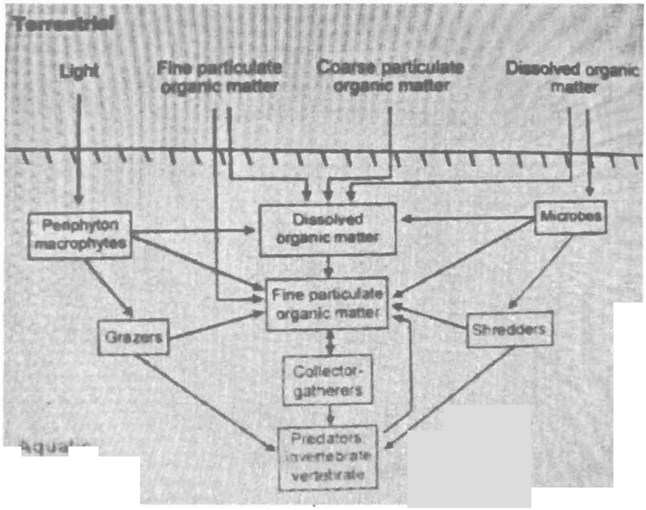


Figure 5. Processes in the convertion of DOM and CPOM to FPOM (Allan 1995).

3. MY CONTRIBUTION TO KNOWLEDGE

3.1 The need to develop and sustain freshwater conservation programmes in Nigeria

The Vice-Chancellor Sir, during the early stage of my career as a lecturer carrying out research in Aquatic Entomology, I realized the need, just like any other environmentalist, for Nigeria to have a framework for the conservation of the ecological integrity of its numerous freshwater ecosystems. I launched my research career with studies on the ecology of a very important pollution sensitive group of aquatic insects, the mayflies (Fig. 6), using reference site approach. I compared the water quality and seasonal abundance of mayflies of a relatively pristine lake in the International Institute of Tropical Agriculture (IITA) with that of impacted stream-reservoir system (Awba Dam) in the University of Ibadan (Ogbogu, 1991).

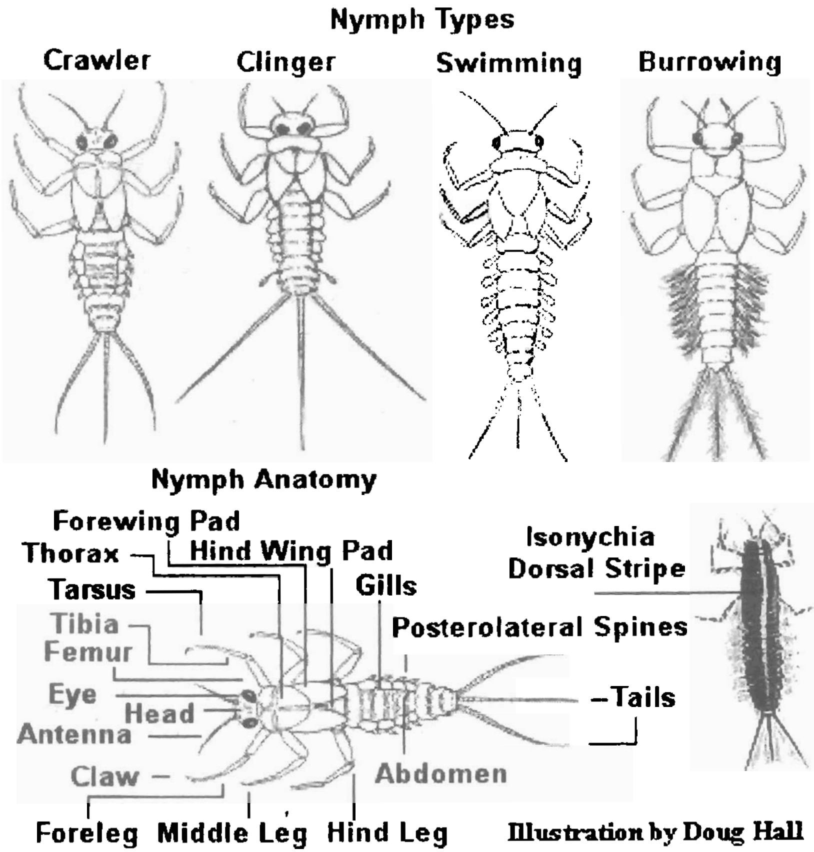


Figure 6. **Mayfly nymphs (larvae) (www.delawareriverguide.net)**

The mayfly communities found in both water bodies belonged to three families and were made up of eight species (Table 1). The record of the *Cloeon* species in that study expanded their distribution map in Nigeria and beyond.

Table 1: List of Afrotropical Ephemeroptera found in IITA Lake and Oba Stream/Reservoir system (Ogbogu 1991).

Family and Species	IITA Lake	Oba Stream/Reservoir
Baetidae		
Cloeon areolotum Navas	+	+
Cloeon cylindroculum Kimmins*		+
Cloeon gambiae Gillies**	+	+
C. perkinsi Barnard	+	+
C. smaeleni Lestage		
Ophelmatostoma kimminsi Waltz & McCafferty***	+	-
Polymitarcyidae		
Povilla adusta Navas	+	-
Caenidae		
Caenis s.l. sp.	+	+

'+' and '-' indicate occurrence and absence of the species respectively in the sampling sites.

*Now known as *Procloeon cylindroculum.*

**Laval stage still confused with *C. perkinsi.*

***Now known as *Ophelmatostoma camerounense.*

Mr. Vice-Chancellor Sir, it is worthy of note that the record of *Caenis* sp. in that study was an addition to the six known species in Africa as at 1991. Moreover, the polymitarcyid *Povilla adusta* was recorded for the first time in Nigeria (Fig 7).

Figure 7. Larva of *Povilla adusta* Navás (Corbet 1957).

There was significant correlation between some inorganic ions in the water and the abundance of *Cloeon* larvae in areas impacted by treated sewage in IITA Lake. My first publication in a scientific journal was based on a curious observation in which phoretic association occurred between a *Caenis* sp. larva and the bryozoan *Plumatella* sp. statoblast (Ogbogu, 1993) (Fig. 8).

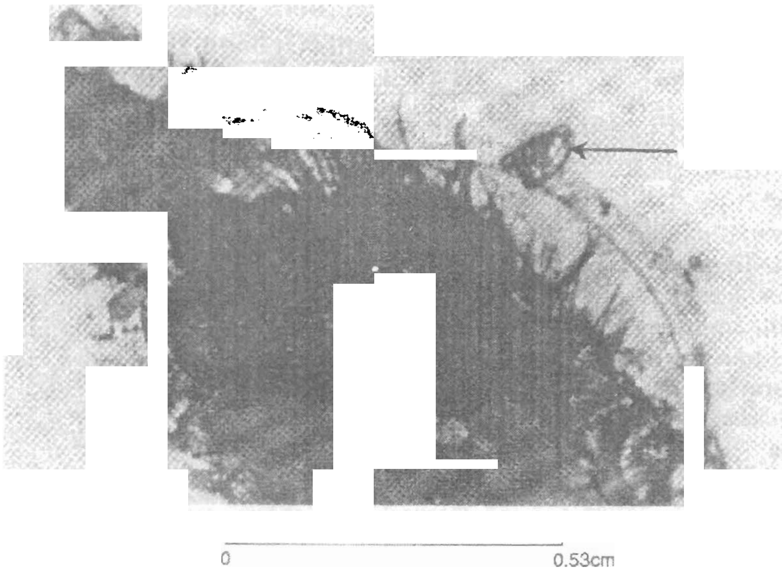


Figure 8: Abdominal region of *Caenis s.l.* sp. with arrow showing *Plumatella* sp. attached to the gill cover (Ogbogu 1993).

The statoblast is a dormant stage which normally drifts on water surface but on germination adheres to any handy object. Its association with the mayfly larva was considered accidental but it may aid in dispersal as in the cases between mayflies and other invertebrates (Disney 1971, Gillies and Elouard 1990).

In another study, we (my supervisor and I) concluded that sewage outfall was responsible for the wide fluctuations in pH, total alkalinity, free carbon dioxide, dissolved oxygen, and reduction in the abundance of the mayflies, *Cloeon* and *Caenis* in Awba stream-reservoir system in the University of Ibadan (Ogbogu and Hassan 1996a). Having noted the influence of water quality parameters on the abundance of *Cloeon perkinsi* larvae, I subsequently sought to determine the effect of individual ions on the most abundant and ubiquitous species of *Cloeon*, *C. perkinsi* in the laboratory. From a 48hr laboratory static bioassay, it was observed that phosphate ion was more harmful to the insect larvae while the LC_{50} was 13.5mg/L for nitrate. The conclusion from that study (Ogbogu, 2003) was that among many species of mayflies, *Cloeon* was a good candidate for water quality assessment in the water bodies.

An earlier study with the same objective had established the optimum ranges of water temperature and dissolved oxygen concentration for the survival of the *Cloeon perkinsi* larva in the laboratory. The 24hour LC_{50} for oxygen was found to be 4.35 ± 0.141mgl^{-1} (Fig 9a), while temperature ranged from 20 to 25°C with lower and upper LT_{50s} being 7.5°C and 35°C respectively (Fig 9b), (Ogbogu and Hassan 1996b). I also concluded in another study (Ogbogu 1999), that the mayfly *Povalla adusta* was warm-adapted, after establishing that the temperature for maximum hatching success of its eggs was around 33.20°C.

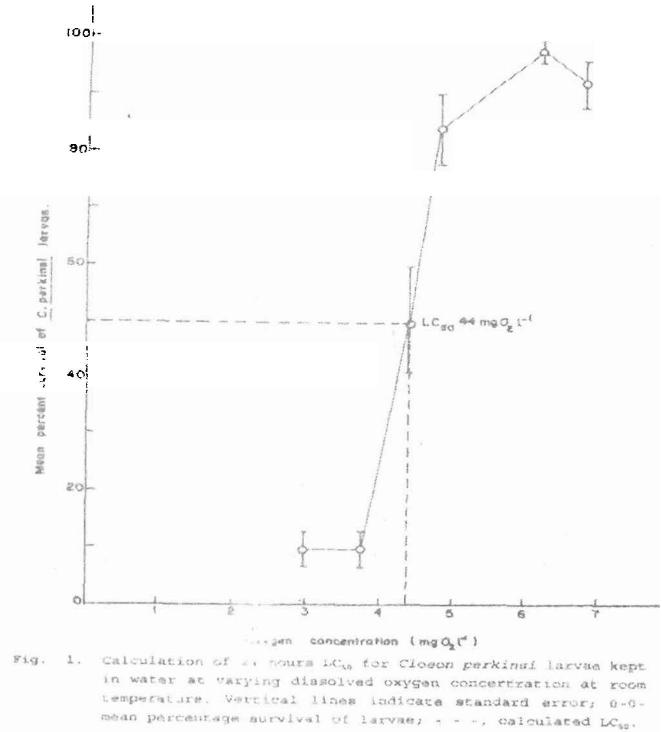


Figure 9a: Oxygen tolerance in *Cloeon perkinsi* larvae (Ogbogu and Hassan 1996b).

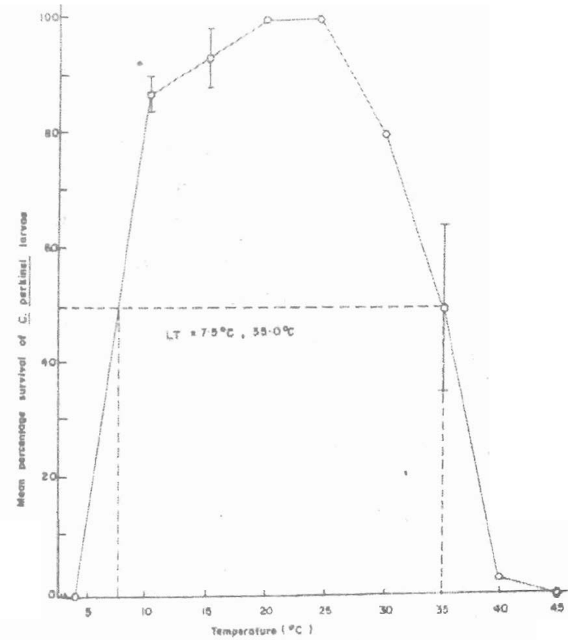


Fig. 2. Calculation of 24 hours LT_{50} for Cloeon perkinsi larvae kept at varying water temperature. Vertical lines indicate standard error; -0-0, mean % survival, - - -, calculated LT_{50}

Figure 9b: Temperature tolerance in *Cloeon perkinsi* (Ogbogu and Hassan 1996b).

The Vice-Chancellor Sir, the quest for baseline data on which strategies for conservation of freshwater ecosystems in Nigeria could be based led to further studies on reservoirs. Attention was focused on Opa Reservoir with a study spanning two years. The study revealed that just like the IITA lake in Ibadan, Opa Reservoir in Ile-Ife was dominated by two mayfly genera, *Cloeon* and *Caenis*, and that water current velocity and submerged aquatic plants determined their distribution and abundance (Fig 10) (Ogbogu 2001a).

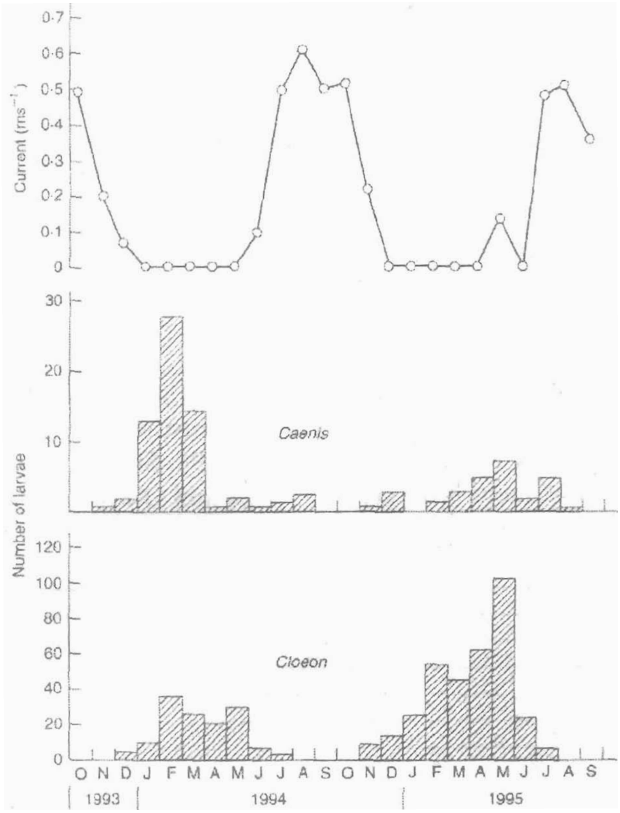


Figure 10. Monthly mean number of *Cloeon* and *Caenis* (Ephemeroptera) larvae and monthly fluctuation in water current velocity at Station 3 in Opa stream-reservoir system (Ogbogu 2001a).

My other studies on the reservoir paid attention to the stream below the reservoir where I observed the vital role the aquatic moss, *Fontinalis* species (Bryophyta) played in the phenology (annual larval recruitment and adult emergence) of hydropsychid caddisflies (Ogbogu 2000, 2001b, Ogbogu and Akinya 2001).

To characterize the water bodies in Ile-Ife, I started with a study in an adjoining stream which is part of the Opa River tributary network. The stream receives treated sewage effluents from the twin sewage oxidation ponds in Obafemi Awolowo University, Ile-Ife. From the observed low diversity and populations of pollution sensitive aquatic organisms, it was inferred that the forest stream ecosystem was impaired. Significant difference was observed in the number of individual macroinvertebrates and community structure between two stations located upstream and downstream of the sewage ponds' point source discharge. The preponderance of the pollution-tolerant chironomid larvae indicated a stressed stream ecosystem resulting from the ponds' effluent discharge (Tab. 2), (Ogbogu and Olajide 2002).

Table 2. Composition, distribution and abundance of macroinvertebrates in two stations in a forest stream in Obafemi Awolowo University in May to November 1998. Station 1 above, and Station 2 below effluent discharge (Ogbogu and Olajide 2002).

Taxon	Station	May 29	Aug 27	Sept 11	Sept 29	Oct 14	Oct 25	Nov 06	Total
Coleoptera	I	0	1	2	0	2	0	0	5
	II	1	3	3	0	4	3	2	16
Crustacea (Crabs)	I	3	1	1	0	0	0	0	5
	II	0	0	0	5	0	1	0	6
Ostracoda (*Cypris* sp.)	I	0	0	1	0	0	0	0	1
	II	0	10	0	0	0	0	0	10
Diptera (Chironomidae)	I	0	0	0	0	0	0	5	5
	II	**16**	**82**	**45**	**9**	**90**	**77**	**111**	**430**
Diptera (Mosquito larvae)	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	2	5	10	17
Ephemeroptera	I	14	7	0	1	1	0	0	23
	II	14	2	4	0	5	10	0	35
Odonata: Zygoptera	I	1	17	9	8	8	23	12	78
	II	1	19	45	32	22	51	20	190
Odonata: Anisoptera	I	0	1	0	0	0	0	0	1
	II	5	0	0	5	0	21	5	16
Total number of taxa	I	3	5	4	2	3	1	2	6
	II	5	5	4	4	5	7	5	8
Total number of individuals	I	18	27	13	9	11	23	17	118
	II	37	116	97	51	123	168	148	740
Total		**55**	**143**	**110**	**60**	**134**	**191**	**165**	**858**

3.2 Aquatic insect faunistics

Mr. Vice-Chancellor Sir, a shift in my research focus was enunciated following my communication with late Professor Mich. T. Gillies. He advised that since Nigeria's aquatic insect fauna were largely unknown, it would be logical to embark on faunistics studies in Nigeria's freshwater bodies. By so doing errors in the identities of species under study would be avoided. Besides, a framework for characterization of aquatic insect fauna and community structure in water bodies could be developed to enable and enhance conservation strategies for them in future.

I had earlier reported the occurrence of the heptageniid mayfly genus *Compsoneuria* (Eaton) for the first time in Nigeria, thereby providing additional information on its distribution range in Africa (Ogbogu and Jagun 1999). This was followed by several reports describing many genera and species that were hitherto unknown as part of Nigeria's aquatic insect fauna. The first outcome from the new research foray was a description of the macronematine *Aethaloptera dispar* Brauer (Ogbogu 2005) (Fig. 11), whose morphological features suggested a form distinct from those earlier described for the same species elsewhere in the West African subregion.

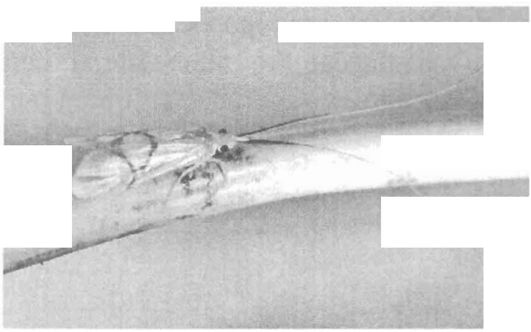


Figure 11. Adult a macronematine species of Trichoptera. Photo: Isaac Ehikhamele.

In the larva, the anterior margin of the frontoclypeus was excavated and the foretrochantin had more setae at the distal area than in other species (Fig. 12). This disparity was attributed to possible link between polymorphism and adaptation to habitat and climatic conditions in the species.

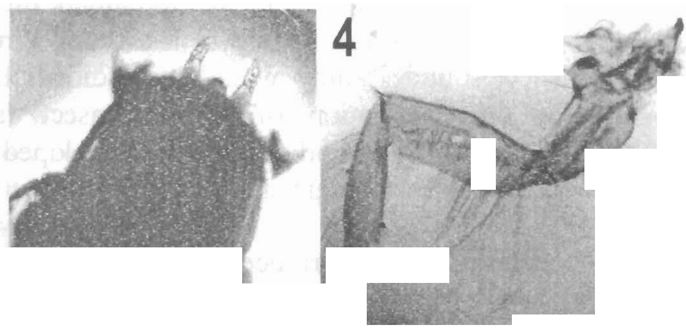


Figure 12. Dorsal views of Frontoclypeus and left foreleg of *Aethaloptera dispar* (Ogbogu 2005).

Descriptions of more species of caddisflies highlighting differences in morphological features from known species were equally carried out. For *Anisocentropus* species McLachlan (Ogbogu 2006a), the larvae described appeared similar but could be separated from *A. usambarensis* and other species by the presence of spines on the lateral margin of the pronotum. In addition, the ventral apotome of the head has an anteromedian depression and flat at the anterolateral corners (Fig. 13). A subsequent description of a male adult bred out of larva confirmed this species as *A. usambarensis* (Ogbogu 2009).

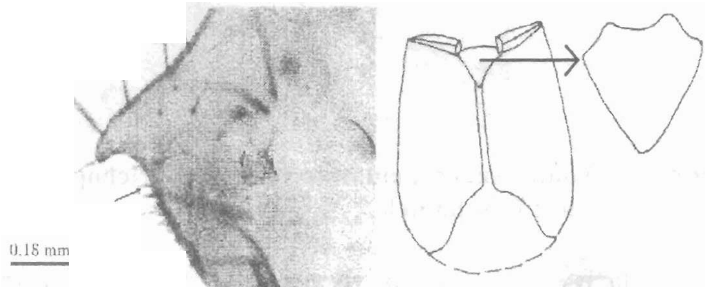


Figure 13. *Anisocentropus* sp. larva: Left lateral margin of pronotum (left), and ventral side of head showing anterior ventral apotome (right) (Ogbogu 2006a).

Examining the larva and adult male of the most common and abundant hydropsychid caddisfly observed in a previous study (Ogbogu 2001b), I identified the species as *Cheumatopsyche digitata* Mosely (Ogbogu, 2006b), although it did not perfectly fit into the key to the adult *C. digitata* in Satzner (1984). Unlike in Statzner's (1984) *C. digitata,* the distance between the anterior and posterior lateral setal area is shorter than the distance between the anterior and posterior margin of anterior lateral setal area in the head. In the larva, the incision by the left side of anterior margin of frontoclypeus is deeper than the one in the right. The posterior arm of foretronchantin does not have as much setae as that figured for *C. digitata* in Statzner (1984) (Fig. 14). My conclusion on these findings highlighted the relationships among several species of *Cheumatopsyche* which made it difficult in separating the species, but was hinged on previous reports on its microhabitats and distribution pattern. It associates with moss (Bryophyta) as observed by Hynes (1975) and Ogbogu (2001b) in intermittent streams where its abundance is usually high and responds to increase and decrease in stream discharge.

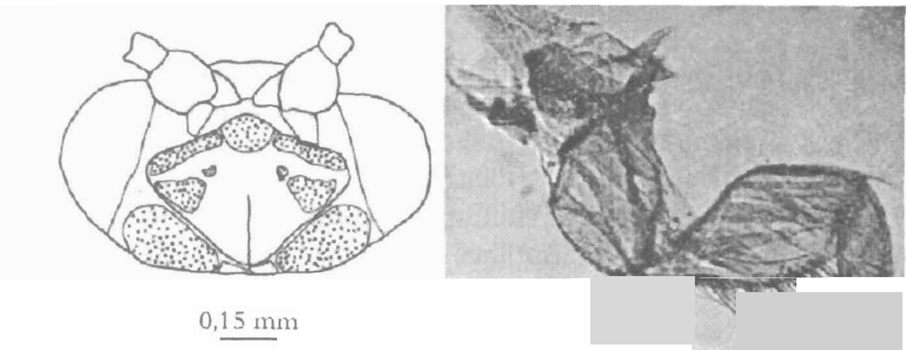


Figure 14. ***Cheumatopsyche digitata*** **(Mosely, 1935): Dorsal view of head showing setal areas in adult male (left), and midleg of larva showing the anterior and posterior arms of the foretrochantin (rght) (Ogbogu 2006b).**

It is generally believed that *Macrostemum alienum* Ulmer occurs more in the transition zone between the northern 'dry' savannah and sometimes in southern lowland forest regions, where water current velocity and length of dry period in streams were identified as factors influencing its distribution. But based on the locality of the material collected and examined (Fig. 15), it was concluded that the species can also be found in tropical rainforest region, which is wetter than the adjacent savannah region towards the north (Ogbogu and Adu, 2006). This led us to conclude that *M. alienum* is highly plastic and distributed beyond what was known from previous studies. As such it may be as widely distributed as its congener, *M. capense* Walker, as noted in Scott (1983).

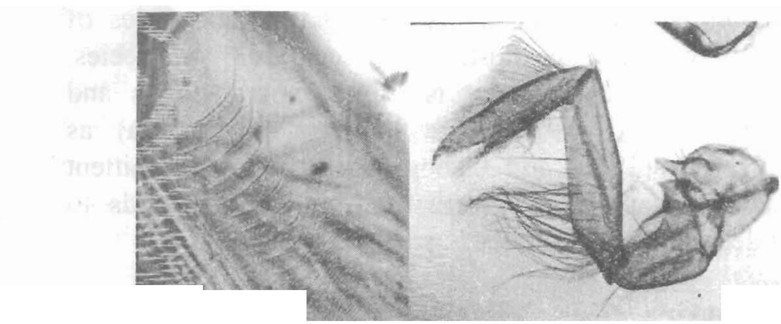
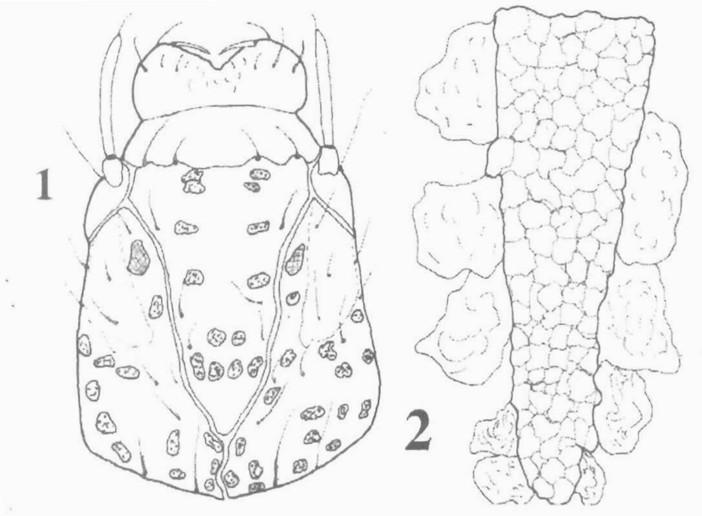


Figure 15. *Macrostemum alienum* larva. Ventral view of head showing stridulatory ridges (left), and dorsal view of right foreleg (right).

My analysis of reports on the Afrotropical species of the leptocerid caddisfly genus *Oecetis* McLachlan yielded an apparent lack of knowledge of the fauna in the region. To address this, I studied the mature larva of an unnamed species of the genus from the stream below Opa Reservoir, Ile-Ife, and successfully separated it from other Afrotropical species (Ogbogu 2008). The distinction was based on the pattern of arrangement of 14 muscle scars on the frontoclypeal apotome and the dorsoventrally compressed larval case with large rock fragments (ballast stones) that are laterally attached (Fig. 16). The species shares the case type with the North American species, *O. nocturna* Ross, which belongs to the *Oecetis*

(Oecetis) furva group. To determine the actual identity of this species, I recommended more collection and rearing of larvae for larva-adult association.

1



2

Figure 16. ***Oecetis* sp. (larva): 1. Head (dorsal view) showing muscle scars; 2. Larval case (dorsal view) showing laterally attached rock fragments (Ogbogu 2008).**

As observed in *Oecetis*, the identities of African species of the leptocerid *Triaenodes* McLachlan are lacking. Efforts at tackling this problem were directed at the description of only the adults of some West African species (Anderson and Holzenthal 2001, 2002). This made the knowledge of the species of the genus in the subregion far-fetched, given the poor knowledge of the larvae. My contribution to the knowledge of this genus in West Africa is a description of the larva of an unnamed species (Figure 17a and b) collected from a forested and well-shaded perennial stream in Obafemi Awolowo University, Ile-Ife, where it closely associates with organic debris (Ogbogu and Okeze 2008).

Figure 17a. ***Triaenodes*** **sp. larval case, (Ogbogu and Okeze 2008).**

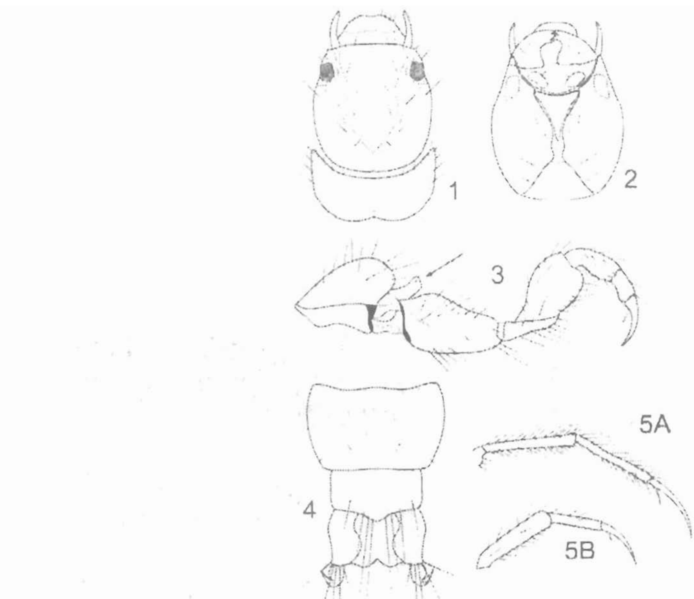


Figure 17b. ***Triaenodes*** **sp. (larva). 1. Head and pronotum, dorsal view. 2. Head, ventral view. 3. Foreleg with foretrochantin (arrowed), leteral view. 4. Abdominal segments VIII – X and anal prolegs, dorsal view, 5A, Hind leg and 5B middle leg tibia and tarsus, lateral view (Ogbogu and Okeze 2008).**

Mr. Vice-Chancellor Sir, the search for taxonomic data on the aquatic insects of southwestern Nigeria also led to my description of a new species of mayfly from Opa River catchment basin named

Afronurus opa sp. n., (Ephemeroptera: Heptageniidae) (Ogbogu and Oyewole 2007). Following the revision of the heptageniid mayfly genus *Compsoneuria* (Webb *et al.* 2006), the identity of the unknown species earlier described in Ogbogu and Jagun (1999) was confirmed as *C. njalensis* (Ogbogu 2007). In a similar study, the perliid stonefly *Neoperla* sp. (Needham) was reported for the first time in Nigeria (Ogbogu 2006c).

3.3 Urbanization and freshwater biodiversity

Having identified some members of the aquatic insect fauna, the next was to see how some of them responded to human disturbance and environmental heterogeneity. I chose caddisflies, one of the EPT (Ephemeroptera, Trichoptera and Plecoptera) taxa, whose members are quite sensitive to aquatic pollution. As a starting point, my postgraduate student and I carried out a detailed study on life history and density of *C. digitata* larvae below Opa Reservoir spillway and found that as suggested in previous studies, the highest larval density occurred in October during the bloom of the moss *Fontinalis* sp. (Bryophyta) (Figs. 18). We also observed that larvae appeared first in July during maximum stream flow velocity and disappeared as a result of adult emergence in January during reduced velocity. Using a morphometric character (head capsule width), we observed five larval instars for *C. digitata* in the spillway (Fig. 19). We were able to infer the insect's dependence on the moss for its peculiar univoltine life cycle below the reservoir (Ogbogu and Adu 2011). This adjustment in life cycle and production is an adaptation to an unstable habitat occasioned by changes in flow regime and water discharge below the reservoir. Habitat alteration adversely affects aquatic insect populations, hence changes in the food web and general ecology of freshwater systems.

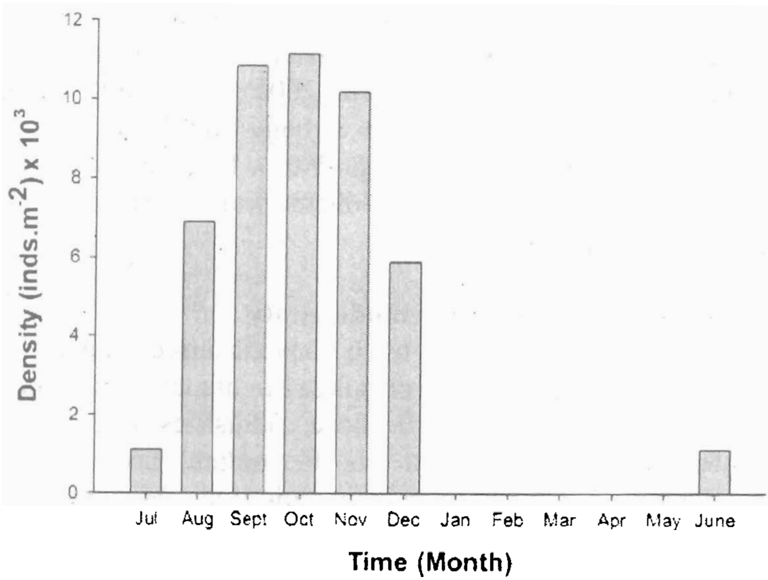


Figure 18. Density of *Cheumatopsyche digitata* larvae below Opa Reservoir spillway (Ogbogu and Adu 2011).

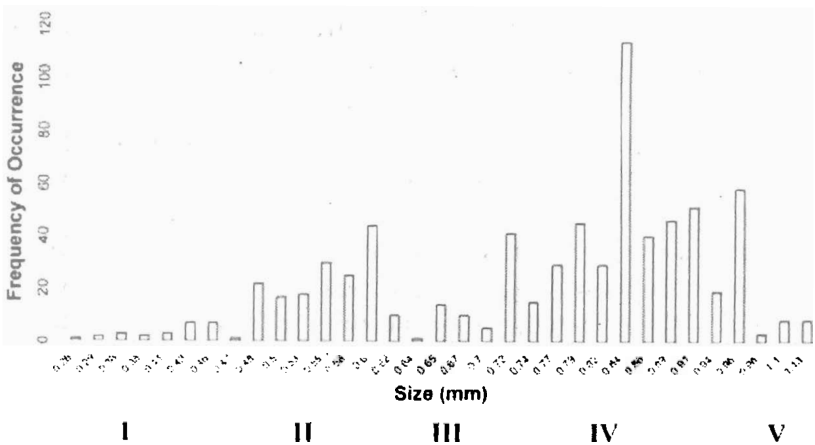


Figure 19. Size frequency distribution of the head capsule widths of *Cheumatopsyche digitata* larvae below Opa Reservoir spillway. I – V = larval instars (Ogbogu and Adu 2011).

Taking the investigation on caddisflies beyond the freshwater ecosystems in the university, we investigated some streams in Ile-Ife metropolis along with those in Obafemi Awolwo University premises to determine how human activities impacted on the distribution and abundance of caddisflies (Amusan and Ogbogu 2013). Six species in six genera and three families were encountered. Of these, *C. digitata* was most abundant (Fig. 20) and widely distributed in the water bodies sampled (Tab. 3).

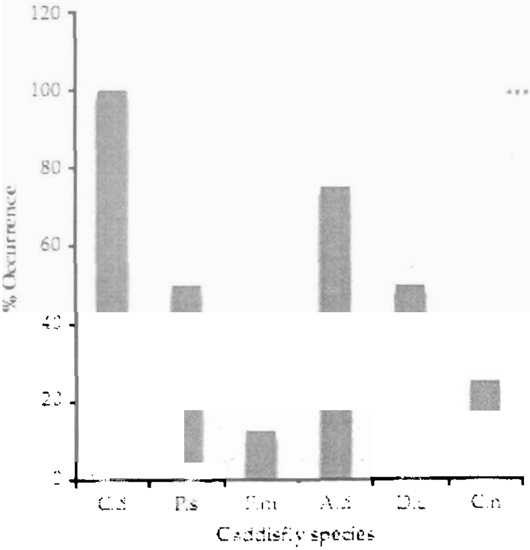


Figure 20. Distribution of the caddisfly species in the sampling stations in Ile-Ife (relative to the total number of sampling stations). C.d, *Cheumatopsyche digitata*; P.s, *Polymorphanisus similis*; P.m, *Pseudoneureclipsis mlangensis*; A.d, *Aethaloptera dispar*; D.c, *Dipseudopsis conformis*; C.n, *Ceraclea njalaensis*. (Amusan and Ogbogu 2013)

Table 3. Occurrence of caddisfly species in sampling stations (streams) located in Ile-Ife metropolis. '+' indicates the occurrence of the species in the sampling stations; '-' indicates the absence of the species in the sampling stations (Amusan and Ogbogu 2013).

Stream location	Caddisfly species					
	C. digitata	*P. similis*	*P. mlangensis*	*A. dispar*	*D. conformis*	*C. njalensis*
Opa	+	+	-	+	+	
Road I	+	+	-	+	+	+
Obudu	+	-	-	+	-	-
Parks & gardens	+	+	-	+	-	-
Reforestation	+	-	-	-	-	-
New Garage	+	+	+	+	+	+
Mayfair	+	-	-	+	-	-
Olonade	+	-	-	-	+	-
% Occurrence	100	50	12.5	75	50	25

There was evidence of high level of human activities as some water bodies (e.g. Obudu, Mayfair and Olorodo streams) had very low populations of caddisflies (Tab. 4).

Table 4. Number of individuals of species of caddisflies collected from sampling stations (streams) located in Ile-Ife metropolis (Amusan and Ogbogu 2013).

Stream location	Caddisfly species						Total
	C. digitata	*P. similis*	*P. mlangensis*	*A. dispar*	*D. conformis*	*C. njalensis*	
Opa	46	9	0	19	23	5	102
Road I	119	24	0	42	51	9	245
Obudu	76	0	0	15	0	0	91
Parks / gardens	17	7	0	11	0	0	35
Reforestation	25	0	0	0	0	0	25
New Garage	71	30	6	50	39	17	213
Mayfair	17	0	0	9	0	0	26
Olonade	13	0	0	0	4	0	17
Total	**384**	**70**	**6**	**146**	**117**	**31**	**754**

Contrary to our expectation, some water bodies in the university appeared highly impacted (e.g. the stream in Reforestation area) with low populations of caddisflies as well. At this point it is necessary to draw attention to an example of obvious cases of impact of urbanization on water bodies. Large quantities of non-degradable waste materials are deposited into drainages and stream channels in Ile-Ife, much of which find their way into Opa Reservoir as shown in (Fig. 21). We all know that these pollutants will cause serious pollution if measures are not taken to reduce their inflow into the reservoir. Apart from the immediate impact on water quality, the aquatic insect fauna will be completely wiped out. This menace has to be addressed urgently.

Figure 21. Non-degradable waste materials in the channel of the stream supplying Opa Reservoir. Photo: S. S. Ogbogu

3.4 Projecting dragonflies as a focal group in freshwater biodiversity conservation

The Vice-Chancellor Sir, my research interest in aquatic insect faunistics, their distribution and abundance as means of highlighting the effects of urbanization on water quality is further demonstrated by my investigations on dragonflies. Juvenile and adult dragonflies are sensitive to environmental degradation including water quality impairment and forest habitat fragmentation. As human activities continued to impact adversely on freshwater ecosystems, now worsened by the hydrological impact of climate change, it becomes imperative to improve on the robustness of the tools to assess the impacts. However, access to relevant knowledge in designing the tools remains poor because until recently, water quality assessments using aquatic insects largely revolved round EPT taxa metrics. Recent advances made it possible to project Odonata as a focal group in freshwater conservation. In the year 2005, I was invited to participate in a training workshop organized by the Species Survival Commission of the International Union for the Conservation of Nature (IUCN-SSC) in partnership with Wetlands International in Dakar Senegal (Fig 22). The workshop targeted freshwater biodiversity assessment for western Africa, using the IUCN criteria in determining the conservation status of organisms. This was followed up with another workshop to evaluate the freshwater biodiversity assessment project for western Africa in Accra, Ghana in 2006 (Fig 23).

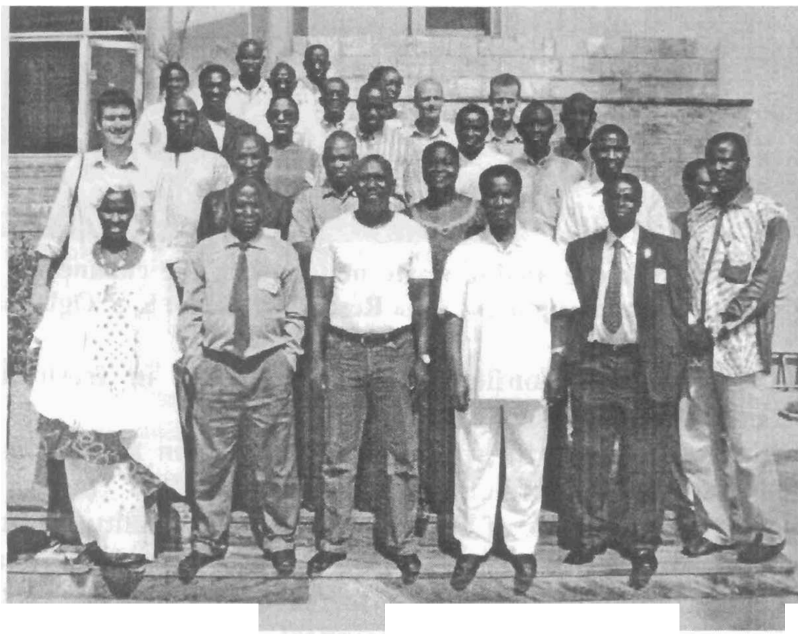


Figure 22. Participants of the training workshop, Dakar, Senegal. Photo: C. Pollock.

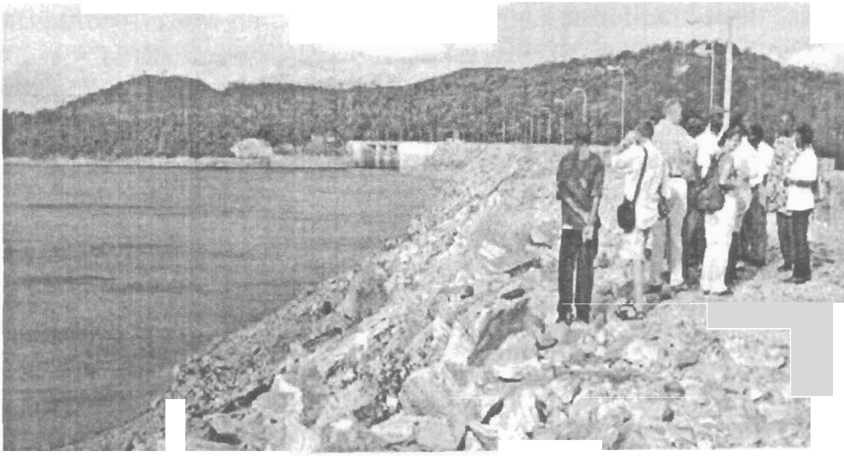


Figure 23. **Participants of the freshwater biodiversity assessment in western Africa overlooking Lake Volta from Ghana's Akosombo Dam. Photo: K.-D.B. Dijkstra.**

In the 2006 workshop, I participated in reviewing the assessments of a number of species including *Chlorocypha glauca* (Selys 1879), *C. radix* Longfield 1959 and *Heliaeschna sembe* Pinhey 1962 (Dijkstra 2010a,b; Claunitzer & Dijkstra 2010). The outcome of the workshops includes my publications on the status of Odonata in the whole of West and other parts of Africa (Dijkstra *et al.*, 2009, 2011). The lessons learnt at the workshops also spurred me to revisit the study of dragonflies of Nigeria with my doctoral degree student. Surveys were carried out in tandem in two contrasting habitats, Obafemi Awolowo University Ile-Ife in Osun State and Apomu Forest Reserve in Ondo State. The short-term goal of the studies was to generate taxonomic, ecological and distribution range data on odonate fauna. The long-term goal was to further advance the use of dragonflies in habitat assessment, hence freshwater biodiversity conservation in the Afrotropical region, with improved data on which Dragonfly Biotic Index (BDI) for Nigeria and neighbouring countries will be based in future.

Mr. Vice-Chancellor Sir, our data on dragonflies of Obafemi Awolowo University revealed 53 species in seven families. Of these, three libelluline and two aeshnid species were recorded as new to Nigeria (Tab. 5) (Fig. 24), (Adu and Ogbogu 2011).

Table 5. Checklist of Odonata species from Obafemi Awolowo University, Ile-Ife, (Adu and Ogbogu 2011).

TAXON	*Assessment category
Libellulidae	
Nesciothemis pujoli Pinhey, 1971	LC
Orthetrum stemmale Selys, 1869	LC
Pantala flavescens (Fabritius, 1798	LC
Aeshnidae	
Heliaeschna longfieldae Gambles, 1967	LC
H. sembe Pinhey 1962	DD

* From IUCN Red list of Threatened Species. LC = Least Concern, DD = Data Deficient.

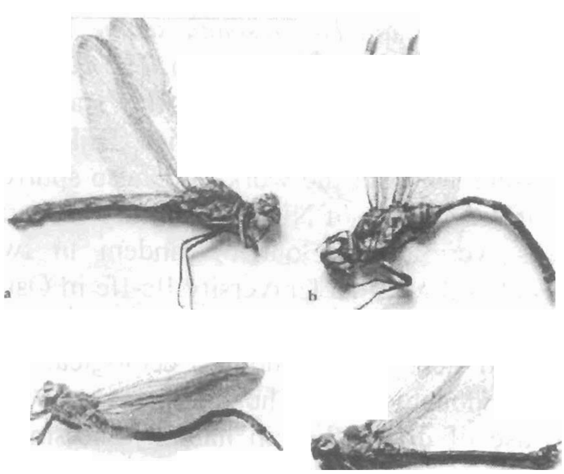


Figure 24. Odanata species of Obafemi Awolowo University, Ile-Ife, Nigeria which are new to the country list. a) *Nesciothemis pujoli* (LC), b) *Orthetrum stemmale* (LC), c) *Heliaeschna longfieldae* (LC), and d) *H. sembe* (DD). All photos are of preserved specimens, (Adu and Ogbogu, 2011).

Our study in Apomu forest recorded 103 odonate species in 44 genera and eight families in which the Libellulidae were the most abundant (Fig. 25), (Adu and Ogbogu 2013). Of these 18 species are new records in Nigeria (Table 6).

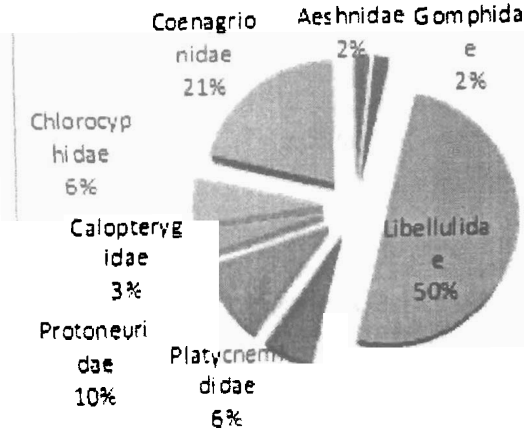


Figure 25. Percentage composition of families of Odonata in Aponmu Forest, May 2008 -2010, (Adu and Ogbogu, 2013).

Table 6: Checklist of new records of Odonata in Nigeria (Adu and Ogbogu, 2013)

Suborder/ Family	Species	*Assessment category
Anisoptera		
Libellulidae	*Atoconeura eudoxia* (Kirby, 1908)	LC
	Micromacromia miraculosa (Longfield, 1947)	NA
	Tetrathemis fraseri Legrand 1977	DD
	Trithemis hatwigi Pinhey 1961	LC
	Zygonoides fuellebonii (Grünberg (1902)	LC
Zygoptera		
Chlorocyphidae	*Chlorocypha radix* Longfield, 1959	LC
	C. pyrifomosa Fraser 1947	LC
Coenagrionidae	*Aciagrion heterostrica* Fraser 1955	DD
	Africallagma vaginale Sjostedt, 1917	NA
	Ceriagrion whellani Longfied 1952	LC
	Pseudagrion bernadi Terzani 2001	LC
	P. bicoerulans Martin 1907	VU
	P. torridum Selys 1876	LC
	Teinobasis alluaudi (Martin, 1896)	VU
Plathycnemidae	*Mesocnemis saralisa* Dijkstra 2008	DD
	Platycnemis nyansana Forster 1916	LC
Protoneuridae	*Elattoneura lliba* Legrand 1985	LC
	E. pasquinii Consigeio 1978	VU

*From IUCN Red list of Threatened Species. DD = Data Deficient, LC = Least Concern, NA = Not Applicable, VU = Vulnerable.

It is worthy of note that although most of the new records are assessed as either Data Deficient, Least Concern or Not Applicable, using IUCN criteria, three are Vulnerable in the threatened category (Fig. 26).

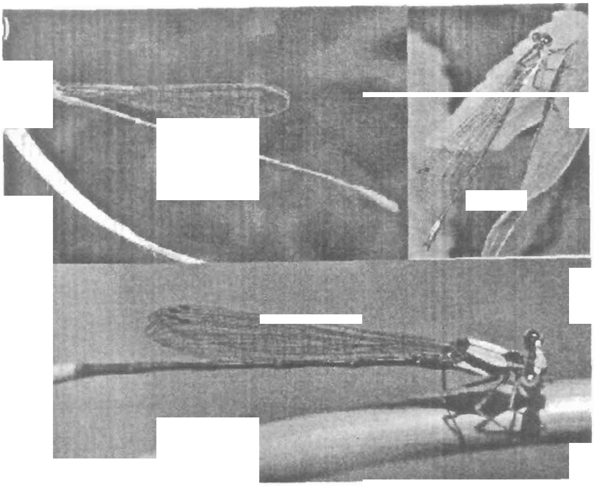


Figure 26. Vulnerable odonate species in Apomu Forest Reserve. *Teinobasis alluadi* (VU) (Top left), Photo: J. Renoult; *Pseudagrion bicoerulans* (VU) (Top right), Photo: A Cordero Rivera; and *Elattoneura pasquinii* (VU) (Bottom) Photo: K-D. B. Dijkstra, (Dijkstra *et al.* 2011).

Urgent and serious attention needs to be paid to deforestation which is a major threat to the populations of the dragonflies. Given the rapid pace of urbanization in Nigeria as a developing country, these species may soon be critically endangered. This is likely to happen if efforts are not made to conserve our freshwater ecosystems and secure the survival of the species. Conserving Odonata and the freshwater biodiversity they represent implies the maintenance of the structural integrity of both larval and adult habitats – i.e. water bodies and their surrounding riparian landscapes.

The Vice-Chancellor Sir, at this juncture let me join all stakeholders in Obafemi Awolowo University in hailing her as Africa's most beautiful campus. But there are 'silent stakeholders', the dragonflies, whose contributions to the beauty of the campus are never acknowledged. Apart from the beautiful coloration they exhibit, they provide considerable freshwater ecosystem services. Their juvenile stages (nymphs) are major players in aquatic food web. They prey on a variety of organisms ranging from infusoria to fish fry. Their waste products also contribute to nutrient cycling in aquatic ecosystems. We need to conserve their micro- and macrohabitats (Freshwater ecosystems on campus) to guarantee their survival and enjoy these services. I hereby suggest that as many forested areas are opened up for infrastructural development on campus, we should be mindful of the adverse effects it has on our water bodies through erosion, siltation and sediment transport in streams as well as unnatural flow regimes. These will drastically reduce the populations of the aquatic insects and their role in the conservation of the integrity of water bodies compromised and eventually eliminated. To avoid this catastrophic situation, forest removal should be minimized, because many dragonfly species are stenotopic. They have very narrow tolerance to environmental disturbance and require shade in the adult stage.

4.0 CONCLUSION AND RECOMMENDATIONS

The Vice-Chancellor Sir, Nigeria can boast of accomplished and eminent scholars in the field of insect science (Entomology) but the dearth of entomologists with interest in aquatic insects is largely evident in Nigerian Universities and research institutes. It is the realization of this that spurred and sustained my interest in Aquatic Entomology research. I consider myself privileged to be one of the few who by the virtue of their training, are aware of the importance of freshwater biodiversity conservation in environmental health and nation building. I have been working hard to deepen this awareness through the teaching of Entomology in general and research in Aquatic Entomology in particular.

Research outputs on the use of aquatic insects as indictors of water quality has led concerned individuals and groups to call for conservation actions to mitigate anthropogenic disturbance in Nigeria's freshwaters. However, the calls may remain fairly effective or ineffective due to the fact that aquatic biodiversity of most of the country's freshwater ecosystems have not been characterized. That is, data are lacking or deficient on the faunistics of Nigeria's freshwater biodiversity. The role of insects in water quality assessments, accentuated by the importance of species identities as presented in this lecture sets the stage for effective freshwater conservation measures in Nigeria.

As a starting point, I hereby call for an inventory of Nigeria's freshwater bodies arranged in groups in terms of type, size, water quality and general ecosystem characteristics. The information should be used to test conservation strategies, develop, implement and regularly update long-term water quality protection programmes. Such programmes should be rooted in proper understanding of local attributes of any given freshwater ecosystem and its watershed to ensure its protection and recovery if impaired. Governments can determine and delineate some freshwater bodies as Freshwater Protected Areas (FPAs) for development of conservation management techniques for use by freshwater scientists, conservationists and managers. Educational materials can be provided to support the public on water quality to ensure awareness and empowerment of freshwater ecosystem stewardship. Above all, governments and private sector can drive the development and evaluation of conservation strategies through massive funding of research and capacity building in freshwater biology.

The Vice-Chancellor Sir, perhaps the easiest and most cost-effective ways of reducing the effects of urbanization on freshwater ecosystems are actions taken at individual and group levels. The use of biodegradable cleaning products to reduce contamination of water bodies cannot be overemphasized. Tree-planting in and around homes can hold soils together and help reduce runoffs. Limited pesticide use reduces the quantity of such contaminants carried into freshwater ecosystems by runoff. Donations to support community projects and volunteering for stream-cleanup help protect freshwater ecosystems for people and nature. Finally, non-governmental organizations (NGOs) with freshwater conservation mandate can partner with governments and academia to shape and implement their programmes.

5.0. ACKNOWLEDGEMENT

Mr. Vice-Chancellor Sir, this lecture will not be complete without appreciating my master's and doctoral degree supervisors, Prof. A. Titi Hassan and late Prof. Samuel Afolabi Toye. They saw the zeal in me and resolved to dedicate their time to midwife the making of a Nigerian Aquatic Entomologist. I will forever be grateful to these erudite scholars and exquisite mentors.

I wish to express my gratitude to Obafemi Awolowo University for providing the platform to realize my dream as an academic in pursuit of knowledge in Aquatic Entomology. The University offered me an appointment as Assistant Lecturer in the Department of Zoology where I rose to become a Professor. I am grateful to my colleagues in the Department for their love, cooperation and support as well as to all my postgraduate students. I thank the Vice-Chancellor Professor Idowu Bamitale Omole and all the principal officers of this University for providing me the enabling environment to pursue my academic career.

I appreciate the support from Emeritus Professors A. E. Akingbohungbe and R. A. Balogun, Professors J. I. Ighalo, J. I. Nwachuḳwu, A. O. Isichei and J. I. Muoghalu. These high ranking scholars have mentored me through the years in my academic endeavours and family life. I thank Dr. A. O. Akintomide, Professors E. A. Agbakwuru and A. A. Salako, and members of Umunna for being there for me and my family. I appreciate the prayers of members of Mount Zion Small Christian Community Apostolate, and the entire Parishioners of Our Lady of Perpetual Light Chapel, pastored by our indefatigable Reverend Father Ayo Abe.

It is my pleasure to acknowledge the tremendous assistance received from late Prof. Mich T. Gillies. He provided the reference materials with which I started as a budding researcher. My

gratitude also goes to my collaborators abroad who thought it wise to be interested in my research focus. I am indebted to Emeritus Professor John C. Morse of Clemson University, South Carolina, USA; Professors Ralph. W. Holzenthal of University of Minnesota, St. Pauls, MN, USA and Karl Kjer of University of California, Davies, USA, for providing the travel grant with which I visited their laboratories to study insect identification using morphological and molecular data. I thank Dr. Oliver Flint Jr. of Smithsonian Institution, USA and Professor Ferdy. C. de Moor of Rhodes University, South Africa for their advice on the study of African caddisflies. To Dr. K-D.B. Dijkstra of Naturalis, Netherlands, I am grateful for his keen interest in my research work on Nigeria's dragonflies and damselflies.

I am highly indebted to my parents, Chief Clement E. Ogbogu (Chinemelu) and Mrs. Rebecca E. Ogbogu (Aru ka akwa) for their unconditional love and parental care for my family through the years. I am grateful to my siblings who have been very supportive in all my endeavours. Some of them have sacrificed their comfort in a number of occasions to ensure that I succeeded as a scholar. I appreciate all my in-laws in general, my Mother-in-law and late Father-in-law in particular, who gave me their daughter as a wife with immense support, and hoped to witness this memorable occasion.

Finally, I express my profound and unreserved gratitude to my nuclear family. I am short of the right words to appreciate the encouragement and care my wife, Dr. Christiana Osaikhiuwu Ogbogu (my Exquisite Jewel) and children have always given me. With prayers, they have demonstrated a high level of understanding and patience, particularly when I spend most of my time in the office and laboratory. I thank the Almighty God for them. I return all the glory to God for no man on earth should give glory to himself.

Mr. Vice-Chancellor Sir, ladies and gentlemen, I thank you all for your attention. God bless you all.

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